aluminum alloy melt is prepared without the addition of grain refiners," (c) DC casting the molten body to form a cast ingot, (d) rolling the ingot into sheet, and (e) electrograining the rolled sheet.

Stated with reference to the rejection of claim 19, the Examiner's position is that Brusethaug et al., directed to the making of offset plates without defects such as fir tree structures, describes a DC-cast sheet ingot of grain-refiner-free Al-Fe-Si alloy, and that it would have been obvious to apply to this ingot the rolling and electrograining steps described by Sawada et al.'827 for producing Al-Fe-Si alloy printing plates from DC-cast ingots.

Applicants respectfully submit that this asserted combination of references would not have been obvious, because Brusethaug et al. does not teach or suggest that ingots without grain refiner could be used to make printing plates, or indeed that grain-refiner-free ingots would have any utility whatsoever.

The only grain-refiner-free ingot mentioned by Brusethaug et al. is the single ingot described at the top of the second column on p. 473 as having "no grain refinement." This ingot, and another of the same dimensions and composition (0.26 wt% Fe, 0.13 wt% Si) but containing 10/1000% Ti (grain refiner), were cast under identical conditions to investigate "The effect of grain refinement on the formation of fir tree zones." The result of this investigation, as reported by Brusethaug et al., was that "The fir-tree zone was only observed in the ingot with a grain refiner addition."

However, Brusethaug et al. clearly shows that two factors were considered important: non-uniform grain and the fir-tree structure. The mere elimination of fir-tree structure, without also overcoming the problem of non-uniform grain structure, would not have been

deemed enough to achieve a satisfactory and usable product, in the state of the art as exemplified by Brusethaug et al.

As the Introduction to Brusethaug et al. states (p. 472, first column), the publication reports "work on the appearance of the fir-tree structure and its dependence upon casting conditions and alloy composition." The Introduction further explains that

> "Certain products like offset plates . . . require a homogenous surface . . . .
>
> "A typical defect . . . is structural streaking . . . which is unacceptable in offset . . . quality. Structural streaking can be the result of a non uniform grain structure (1), segregation or local differences in the primary constituents within the aluminium matrix - the so-called fir-tree structure (2-6)."

Reference (1) is a textbook by D. Altenpohl, Aluminum Viewed from Within (Dusseldorf: Aluminium-Verlag, 1982) of which a copy of the passage (pp. 146-47) cited by Brusethaug et al. is attached hereto. Discussing "Causes of Streaking or Streak-Free Structure After Forming," Altenpohl states that streaks may be "due to large as-cast grains," that "the streaking from large as-cast grains even after severe cold work is not difficult to understand," and that "It is important to avoid coarse grain in all processing steps." Hence, the above-quoted Introduction of Brusethaug et al. effectively teaches that undesirable structural streaking can result (inter alia) from either coarse grains or fir-tree structure.

From this, a person of ordinary skill in the art could only conclude that both coarse grains and fir-tree structure must be avoided in order to prevent structural streaking. Thus, while the investigation reported by Brusethaug et al. is a study of fir-tree structure, aiming "to eliminate the fir-tree structure, or at least to keep the zone width consistently smaller than the scalping depth," there is no implication in the reference that such control of fir-tree structure is a sufficient condition for prevention of

structural streaking and consequent production of satisfactory printing plates.

Reverting again to the description of the single grain-refiner-free ingot mentioned by Brusethaug et al. (p. 473, second column, top), applicants note that immediately after reporting the absence of a fir-tree zone in this ingot, the reference states that "Casting speed and Fe/Si ratio are clearly dominating parameters regarding the fir-tree zone formation." Inferentially, then, the grain-refiner-free ingot did not itself represent a useful or practical solution to the fir-tree zone problem but was merely an investigatory test of one of multiple factors. The Brusethaug et al. publication supplies no thought or suggestion of departing from the standard practice of including grain refiner in any DC-cast ingot that is to be rolled and electrograined for production of printing plates. Rather, Brusethaug et al., taken as a whole, reinforces the view then standard in the art that the presence of grain refiner is essential. So much is evident from the explicit but unambiguous teaching, in the introductory portion of the reference (and specifically in the citation of Altenpohl), that to prevent structural streaking, coarse grains must be avoided - i.e., that grain refiner (to control grain size) is essential.

Certainly there is nothing in Sawada et al. '827 to suggest such a departure from standard practice. An artisan of ordinary skill, considering the two references together, would therefore not be led to suppose that the investigatory grain-refiner-free ingot of Brusethaug et al. could produce satisfactory printing plates if subjected to the process steps of Sawada et al. '827. In other words, the artisan would not find in the two references any motivation to combine them as the Examiner has asserted.

It follows that claim 19, in reciting that the alloy melt is prepared "without the addition of grain refiner" and is subjected to steps of DC casting, rolling and electrograining, presents an

unobvious and patentable distinction over Brusethaug et al., Sawada et al. '827 and any proper combination thereof. The ability of a grain-refiner-free alloy, so processed, to achieve an acceptable product, represents a surprising new result.

It may also be noted that the subjection of the specific grain-refiner-free alloy of the Brusethaug et al. test to the process of Sawada et al. '827 would be contrary to the teaching of Sawada et al. '827 that the alloy should have a content of not more than 0.20 wt.% Fe, and would therefore be unobvious on that ground as well. If the alloy were modified to meet the Sawada et al. upper limit of Fe content, it would be outside of applicants' claimed range.

For the foregoing reasons, it is believed that this application is now in condition for allowance. Favorable action thereon is accordingly courteously requested.

Respectfully,

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I hereby certify that this paper is being deposited this date with the U.S. Postal Service as first class mail addressed to Commissioner for Patents, P. O. Box 1450, Alexandria, VA 22313-1450.

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Aluminum Viewed from Within

An Introduction into the Metallurgy of Aluminum Fabrication

1st Edition

Prof. D. Altenpohl

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Foreword

Prof. Altenpohl's book, "Aluminum Viewed from Within", bridges a gap between physical metallurgy and industrial application of aluminum. Already four editions were printed in German and translations into Japanese and French have been published. There is no other book on the metallurgy of aluminum and its alloys, having such a wide distribution.

Besides its usefulness for students, the main purpose of the book is to arouse the interest of people employed in the aluminum industry to achieve a better understanding of manufacturing processes of the metal and its alloys through a step-by-step explanation. This is accomplished by describing transformations in the metallic structure like the age hardening process, and by providing a certain understanding of metal physics. There is much emphasis placed on the knowledge of structural changes which take place during fabrication of aluminum and its alloys, from the raw material to the finished product. The casting technique is significant not only for the properties of castings but also how the cast structure affects the properties of rolled or extruded products. The steps involved in the fabrication process are divided into mechanical and thermal treatments. In every case, the changes in the properties are based on transformations within the atomic structure of the material.

"Aluminum Viewed from Within" applies to the practical man in the plant, providing a path to metallurgical understanding. The practitioner has no trouble following the subject because the information is presented simply and requires very little previous knowledge of the subject. The book is no less useful to the designer to whom an insight into the specific properties of aluminum and its alloys is indispensable. This book, by the way, is an off-spring of a large volume "Aluminium and Aluminium Alloys", written by the author together with other reknown experts and published by Springer Verlag in 1965. It combines results of classical metallurgy, metal physics and materials technology.

It wish the English edition the same success as the German, Japanese and French editions.

Professor Werner Koester, PhD,
Hon.-Dr. Eng., Director Emeritus,
Max-Planck Institute for Metal Research,
Stuttgart, Germany.

Figure 148d shows the structure of an extruded rod. By far, the majority of the cross-section consists of a fibrous structure, with only the surface showing a thin recrystallized zone. A medium to coarse grain on the surface of extruded shapes cannot be prevented for some alloys, but for the most part its occurence is tolerable, since the stronger fiber structure occupies the greater part of the cross-section. But, the recrystallized surface of the extrusion may be undesirable for decorative applications (increased work required for polishing to avoid streaking).

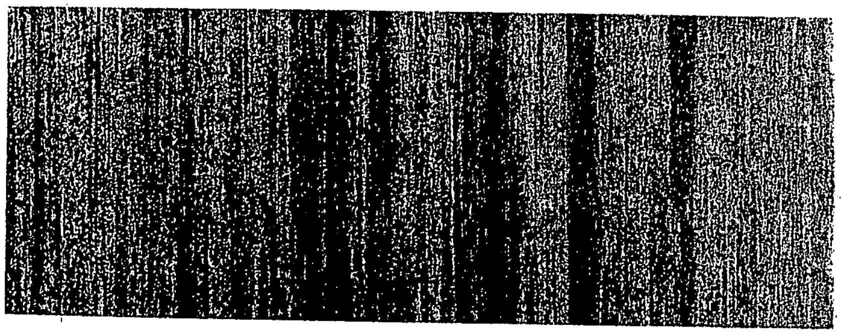

Figure 149: Soft, commercial purity aluminum sheet (etched) with a fine-grained but streaked structure. The streaks are due to large as-cast grains, which become evident again after recrystallizing twice. This streakiness becomes visible after etching or anodizing.

Causes of Streaking or Streak-Free Structure after Forming

The severe reduction in cross-sectional area of 50 : 1 to 80 : 1 during extrusion produces a more uniform structure than is possible in sheet, on which a streaked structure often appears during anodizing (Figure 149). For various reasons it is undesirable to have either a hot-rolled structure which contains non-recrystallized grains from the cast structure, or one with coarse recrystallized grains. The outline of large crystals still present after hot deformation can often be recongized after subsequent cold working (for example, after anodizing, it shows up as a streaked structure).

The streaking from large as-cast grains even after severe cold work is not hard to understand. The as-cast grains are surrounded by heterogeneities. The grain boundary material is not displaced during recrystallization, and is usually elongated only in one direction during subsequent cold work. The localized enrichment of inclusions can be recognized after etching, polishing or anodizing, of sheets or shapes, as a streaked structure, since the inclusions usually are attacked either more or less than the matrix by chemicals and they discolor the anodic film (Figure 149).

In addition to the size of the as-cast grains, their cell size is of importance for the streakiness of the sheet. Large-celled structures or a large variation in the cell size are undesirable (see Figure 39 on page 55). With today's improved DC casting techniques, it is possible to produce rolling ingots with a fine-celled, fine-grained and uniform as-cast structure which produces streak-free sheets.

The situation is similar for coarse grains in wrought material. After sufficient cold work and recrystallization, the original large grains will produce small crystals with similar orientation, regardless of whether the original large grains were as-cast or the result of recrystallization. Thus, even though the final strucure is fine-grained, the original "mother crystal" is recognizable.

It is therefore important to avoid coarse grain in all processing steps, including casting, hot working and intermediate annealing, in order to obtain a finished product with the most uniform surface and forming characteristics possible (quasi-isotropic state). Modern fabrication methods fulfill these requirements for all wrought alloys, with few exceptions.

Furnaces

So far, the fundamental aspects for thermal treatment of aluminum and aluminum alloys have been discussed. It should be kept in mind that heat-treating operations for aluminum are precision processes. Therefore, the furnaces in which the thermal processes are carried out must be designed and maintained properly to ensure reproducibility and uniformity of time-temperature cycles.

The effects of time and temperature, together with the necessity to conduct many treatments at temperatures near the eutectic melting point of the alloy makes close temperature control of an entire furnace charge mandatory during the heat-treatment cycle. Whenever possible load-thermocouples should be used for direct temperature measurement.

Generally, standard types of furnaces and heating equipment can be used for heat-treating aluminum alloys. These include car and truck type, vertical pit and tower, horizontal conveyor, and strip- and sheet-processing furnaces.

The selection of furnace equipment depends on process and product requirements. In practice this means the choice between batch and continuous operation.

Batch furnaces usually permit a greater load density than continuous furnaces. Normally batch furnaces are used for products which are massive and heat slowly, and processes which involve a soak (holding at temperature) so that the heat-treatment cycle is long regardless of the time required to reach temperature. Typically, forgings, cast and extruded parts are handled in batch furnaces.

Batch thermal treatment of coils of wire and sheet present special problems. Coils of these products have poor thermal conductivity in the radial direction which means that they have a much slower heating and cooling rate inside, than at the surface. Therefore, quenching and precipitation treatments are generally not possible. With increasing coil weight (up to 10–20 tons for coils of sheet), variations in strength and grain size become more evident after partial annealing and even full annealing. The very long thermal cycles of more than 24 hours also result in low furnace throughput. Continuous furnaces provide a solution to these problems.

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